HOST

HST ORBITAL SYSTEMS TEST PLATFORM

Post Mission Review

Agenda

Time	Presentation	Presenter
8:30	**HST Project Manager**	*Mike Kienlen*
8:40	**Host Mission Manager**	*Rud Moe*
8:50	**Replan Manager**	*Darrell Story*
9:00	**Thermal**	*Chuck Wiggins*
9:15	**486 Computer**	*Brent Hyatt*
9:30	**NCS Overview/NCC**	*Bob Smith*
9:50	**CPL/Radiator**	*Matt Buchko*
10:15	**ESM / Software**	*Ed Cheung*
10:30	**SAMS**	*Darrell Story*
10:45	**SSR**	*Joe Forsyth*
11:00	**PHA**	*George Stassinopoulos*
11:10	**HOST Controller & S/W**	*Ed Cheung*
11:20	**FOFE**	*Russ Burgess*
11.30	**HOST System Engineering**	*Kevin McAveety*
11:45	**Conclusion & Comments**	*Mike Kienlen*

HST Project Manager

Michael Kienlen

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HST Project Management

- The purpose of this review is to summarize the results of the HOST mission, and to outline any changes to the SM-3 verification programs

- HOST Mission was very successful due to an experienced and very dedicated team of people

- HOST was a high risk flight demonstration mission, which provided lower risk to HST for the Third Servicing Mission
  - 16 months for concept to launch
  - Provided for early development of flight hardware

HOST Mission Manager

Rud Moe

Mission Management

- STS-95 mission parameters
  - Launch date—November 29, 1998
  - Mission Duration—10 days
  - Orbit Altitude—295 x 305 nmi, 28.5 deg incl

Place holder for POCC staffing, mission timeline, comm chart

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Mission Management

- **HOST timeline execution accomplished all mission objectives:**
  - 486 Computer—no radiation upsets
  - NCS performance demonstrated
    - ⇨ NCC stabilized at 72.8 K, limited by environment
    - ⇨ NCC cold start successful
    - ⇨ CPL deprime / restart successful
    - ⇨ CPL conduction demonstrated
    - ⇨ ESM no radiation upsets
  - SSR—radiation errors similar to HST item
  - FOFE—data collection accomplished

Mission Management

- **HOST Carrier and Ground systems performed successfully**
  - HOST Controller, FMDMs, and PDSU suitable for reuse in flight
    - ⇨ Controller reconfiguration will resolve thermal limitation;
    - ⇨ Controller experienced no radiation upsets
  - SAMS data collection accomplished
  - PHA operation supported mission
  - Network configuration exercised NASCOM IP and Shuttle ISP data flows successfully

Replan Manager

Darrell Story

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Replan

- **Mission Objective**
  - Accomplish primary mission objectives of HOST by accommodating contingencies from the Shuttle, the Shuttle experiments, and the HOST experiments
  - Achieve an NCS operating temperature and stability requirements
  - Take into consideration the Shuttle power / energy budget requirements for HOST

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Replan

- **Mission Replan Summary**
  - Extended first and final NCS cooldown periods to accommodate hot thermal environment on radiator
  - Eliminated two of three NCS Idle experiments to
    - ⇨ preserve the CPL deprime / reprime experiments
    - ⇨ increase final cooldown time so as to maximize probability of reaching design operating temperature of 72K
  - Produced 65 ops requests to accomplish mission objectives

- Total HOST Timeline replans = 19 (+ 1 extended mission replan)
- Total HOST Command Plan replans = 3
- Final Timeline replan = 9D
- Final Command Plan replan = 9B

Thermal Engineering

Chuck Wiggins

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Flight Data - HOST Components

	TEMPERATURES ~ C				
COMPONENT	LOW	LIMIT	AVG	HIGH	LIMIT
CONTROLLER	7	-20	20	39	40
NCC RADIATOR	-26	-50	7	22	80
CRYOCOOLER	5	-50	22	34	50
ESM	8	-20	20	36	50
SSR	6	-10	12	28	43
486 COMPUTER	3	-23	14	32	35
FMDM	17	-1	32	46	52
PDSU	8	-40	16	28	40

None of the HOST components exceeded limits during the mission.

HOST Survival Heaters

- Two of the survival heaters were activated during the flight by thermostat operation
- SAM's Electronic Box - very low duty cycle during long duration cold attitudes
- SSR - Operation during each long cold attitude as expected
- No other heaters are known to have been activated
- No survival heater circuits failed to respond at prescribed setpoints

HOST THERMAL FLIGHT ANOMALIES

- The HOST flight was generally warmer than expected
  - Transient warmup during solar attitudes were not that far off from predictions
- Based on cooldown trends, steady state predictions were very close to predictions
  - Transient cooldown was much slower than expected
- Potential reasons for error in cooldown rates
  - Utilization of massless (arithmetic) shuttle and adjacent experiment nodes (Post flight analysis has shown this to be the most likely reason)
- Extremely complicated radiation matrix between HOST and it's surroundings
- Specular re-radiation and trapping of UV Flux-Software does not compute
- Inability to model effectively the very complex MLI coverage of HOST
- Utilization of simple blocking nodes for Spartan and EIH

HST Central Processing Computer (486)

Brent Hyatt

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HST 486

- **Mission Objective**
  - Minimum operating time of 96 hours without any errors relating to radiation
- **Configuration**
  - Strings 1 & 2 operated in pin-pong mode
  - Strings 1 & 3 operated in pin-pong mode
  - Strings 2 & 3 operated in pin-pong mode
- **Results**
  - No errors seen due to radiation
  - Total operating time without error: 193 hours, 16 minutes
    - ⇨ Strings 1 & 2 operated without error for 67 hours, 24 minutes
    - ⇨ Strings 1 & 3 operated without error for 71 hours, 34 minutes
    - ⇨ Strings 2 & 3 operated without error for 54 hours, 18 minutes

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HST 486

- **Changes For SM-3 Acceptance Program (Non-HOST related)**
  - Flight#1 Refurbishment plan:
    - ⇨ Change connectors from JT to LJT (and associated flex circuits).
    - ⇨ Change two PALs and one FPGA on the CPM boards.
      - This will correct parity error problem found during I&T (ref. HAR 1130).
    - ⇨ Change out ASA 2805 DC/DC converters on PCM boards.
    - ⇨ Change out two side panels.
    - ⇨ Change out some resistors per J&T ECNs.

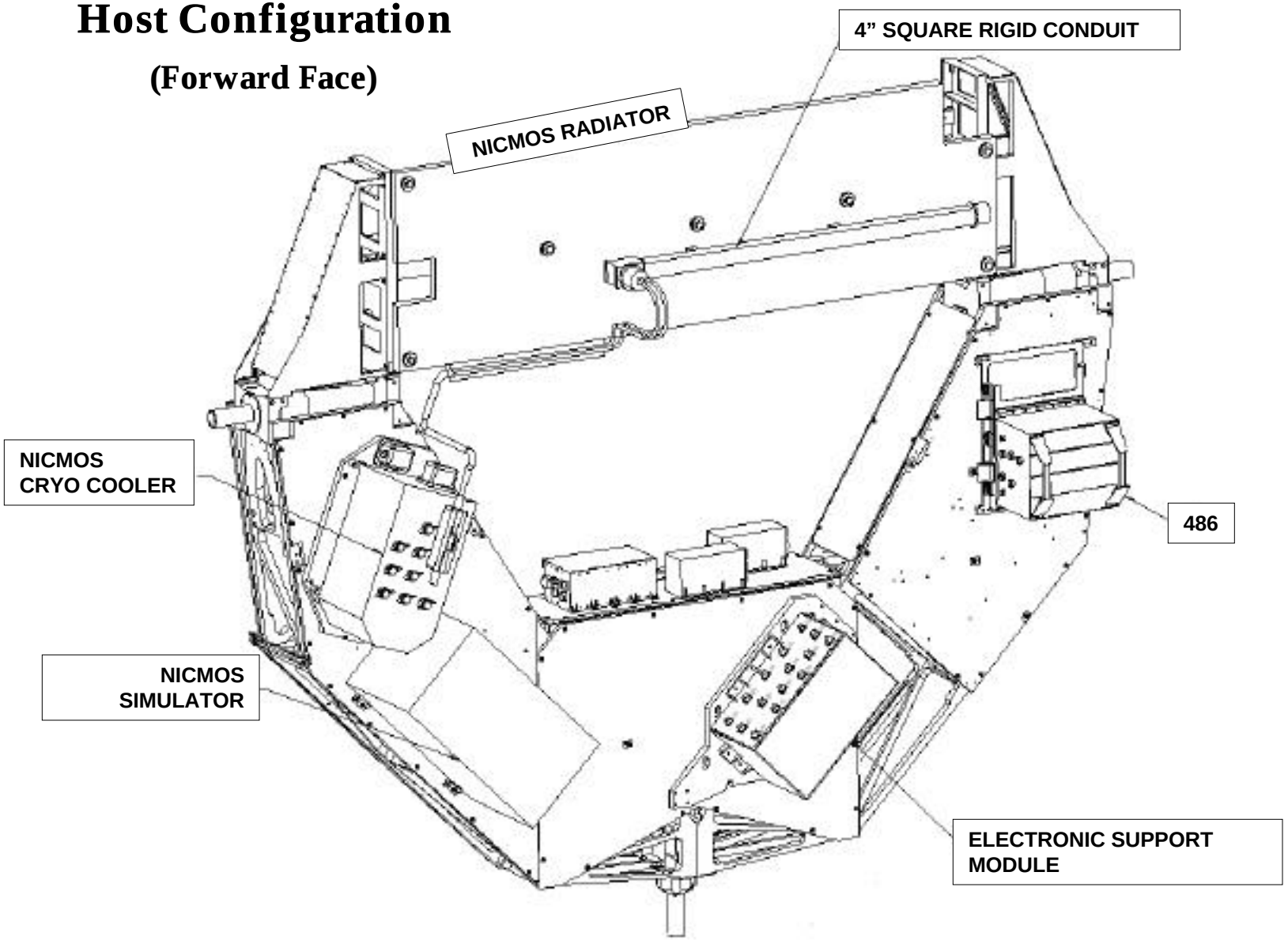
- **Open Issues and Remaining Work (HOST related)**
  - HAR 1159 on Thermistor-B
    - ⇨ With both strings off, showed an offset of approximately 9 degrees
    - ⇨ Data pre-launch showed intermittent offset, checkout to be done during Flight#1 refurbishment.

NICMOS Cooling System
&
Cryo Cooler Overview

Bob Smith

Host Configuration

(Forward Face)



NCS HOST Test Objectives

- Verify Zero Gravity operation
  - NCC Air Bearing Rotating components
  - Capillary Pump Loop 2-Phase flow through Flexible Transport lines
  - Operation of largest heat pipe radiator ever flown
- Measure vibrations emitted by the NCC
- Cool the NCLS Dome temperature to 75k
  - Represents a 77K detector well temperature
- Stabilize the NCLS dome temperature
  - 3600 Seconds within .1K
- Perform an idle mode operation
- Deprime and priming of the Capillary Pump Loop system

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NCC Mission Summary

- **Coldest temperature reached on HOST: 72.6K**
  - Warm Shuttle environment restricted cooling capacity
  - 70K reached during Thermal-Vacuum testing
- **Stabilization validated at three temperature set points**
  - 72.9 K for 1h05m
    - ⇨ Exceeded requirement of 75k
    - ⇨ approached goal of 70K
  - 78.2 K for several hours
    - ⇨ tested stability with 20mw and 400 mw inputs
  - Additional stability periods at 75.2K and 76.7K
- **Temperatures measured at NCLS Cold Plate Dome**
  - Simulates aft end of NICMOS Dewar
- **Cold start of rotating machinery**
  - Compressor, Turbo Alternator started at 165K and 75K
  - Circulator restarted at 75K
- **NCC Operating hours on orbit: ~180**

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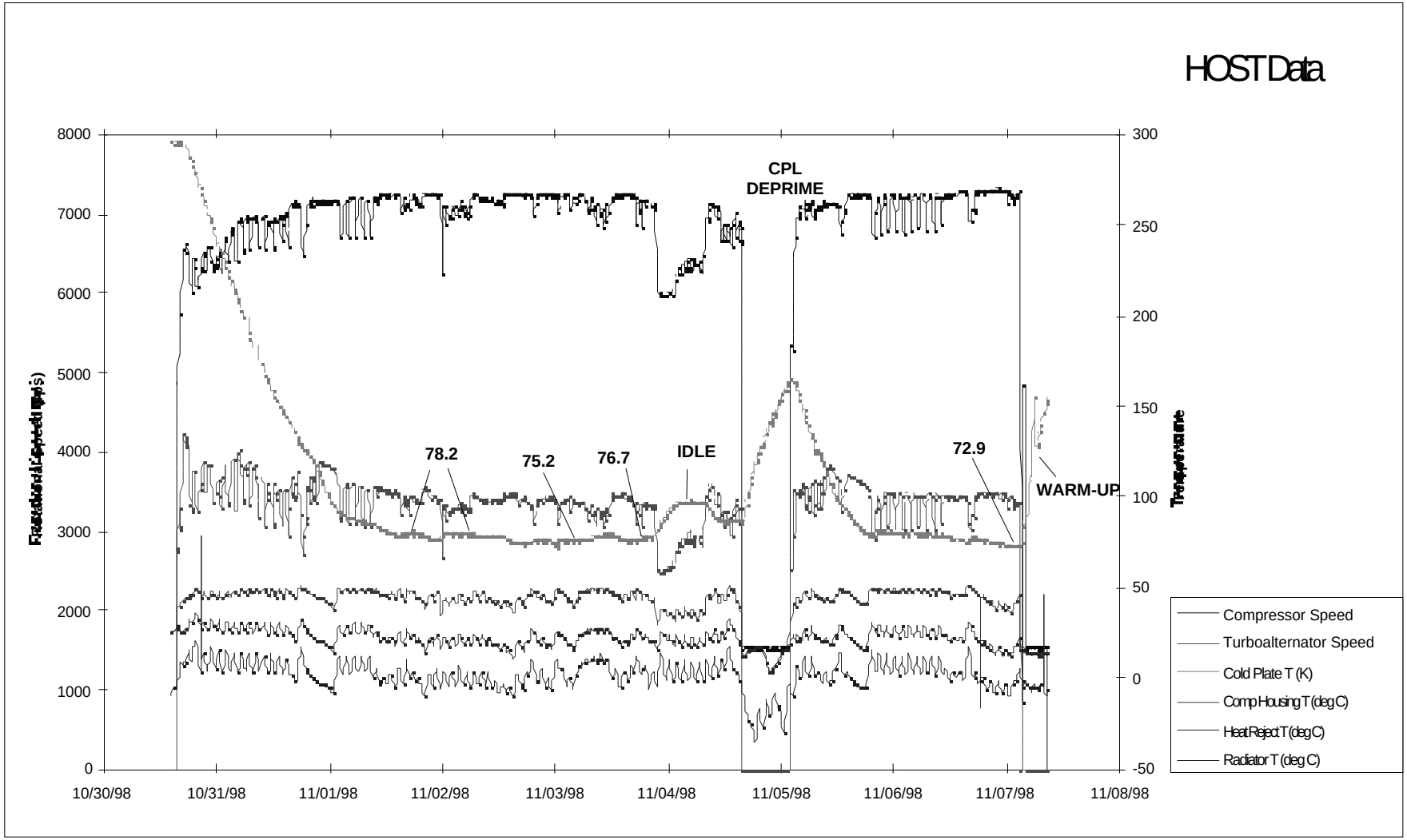
NCC HOST Profile



NCC Stability

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Summary

- STS-95 showed:
  - Miniature rotating components are viable for space use.
  - Cryo-cooler can reach temperatures required by NICMOS on HST
- HOST Mission performance was comparable to TV Testing when the higher environmental temperatures experienced on HOST are accounted for.
- Extreme thermal transients experienced on HOST show the system shall remain stable in the HST environment
- Need to modify some limits and control ops based on lessons learned during mission.

SM3 NCS Upgrades

- Rework Power Conversion Electronics
  - Unified Inverter (no DC/DC Converter)
  - Modified Power Factor Correction network
  - Improved EMI filtering
  - More efficient electrical parts, wiring etc.
- Investigating parasitic heat inputs
  - 1 w parasitic = 45 W input power
- Lab test of Circulator motor
  - Validate changes, if any to Flight Circulator
- CPL Differential pressure sensor removed for SM3
- EVA accommodations to be added to the NCS
- ESM shall be upgraded as planned to include 2nd string redundancy and interfaces for HST

CPL/Radiator

Matt Buchko

CPL/RADIATOR SYSTEM PERFORMANCE SUMMARY

- CPL Performance was 100% Successful
  - No unintentional deprimes, system survived extreme enviromental swings
  - System conductance increased from 22 W/°C to 24 W/°C by varying CPL Control Law Algorithm Parameters
- Two intentional deprime/reprime cycles were completed to demonstrate operational flexibility for SM3 ASCS applications
- Differential Pressure Transducer provided useful information on CPL operations
  - Clearly showed complete vapor blow-through of HPHX1 on MET Day 4 when CPL Control Algorithm was being optimized for performance margin
- CPL appeared to have self-started when Payload Bay doors were opened
  - NCC Heat Rejection Interface was at 12°C, within 1°C of reservoir temperature when telemetry was obtained (about 2.5 hours after door opening)
  - SM3 EVA timeline assumes CPL's will self-start and accommodates this scenario by requiring CPL survival heaters to be enabled prior to attachment of capillary pumps to instruments

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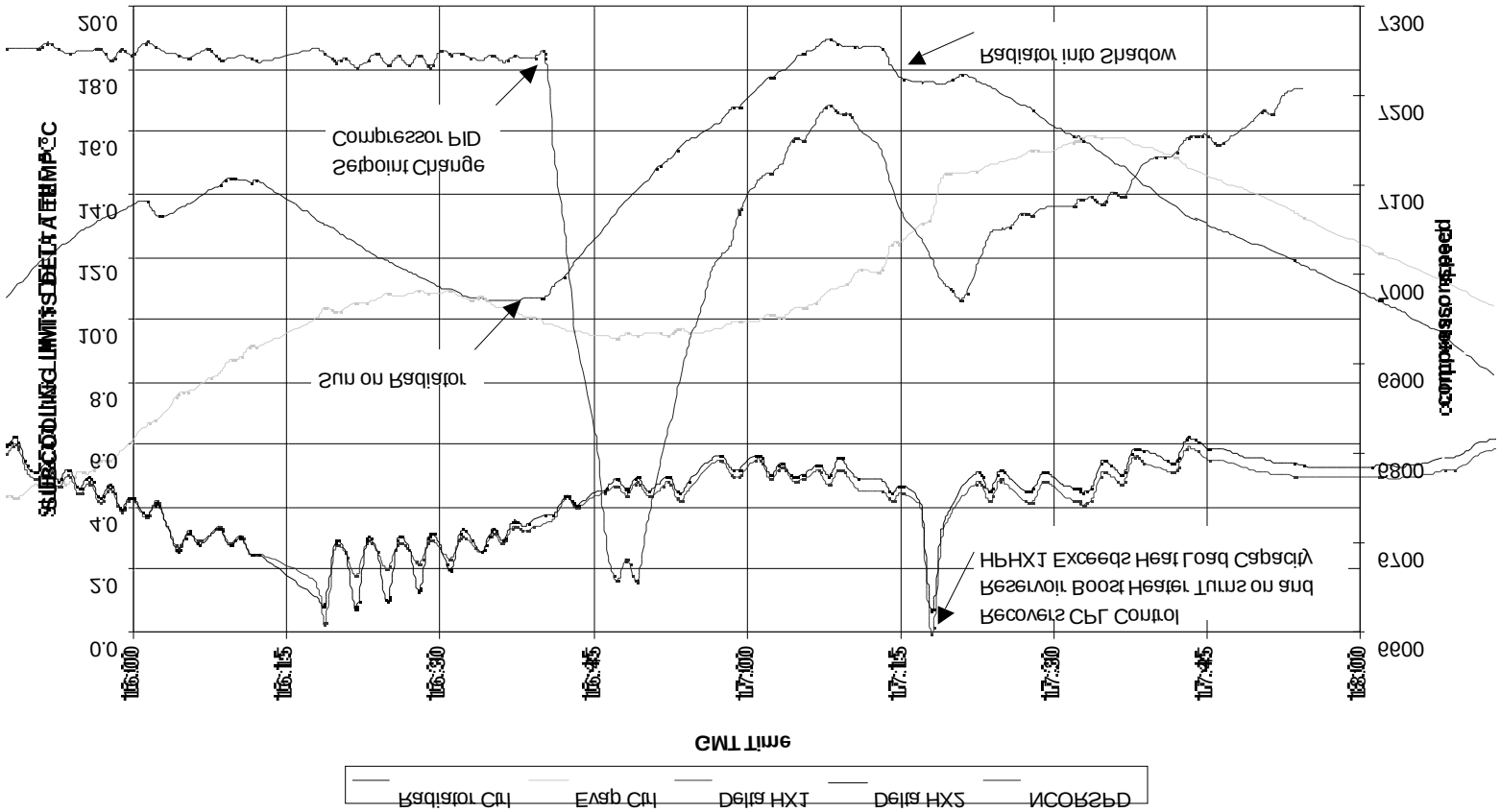
CPL/RADIATOR SYSTEM



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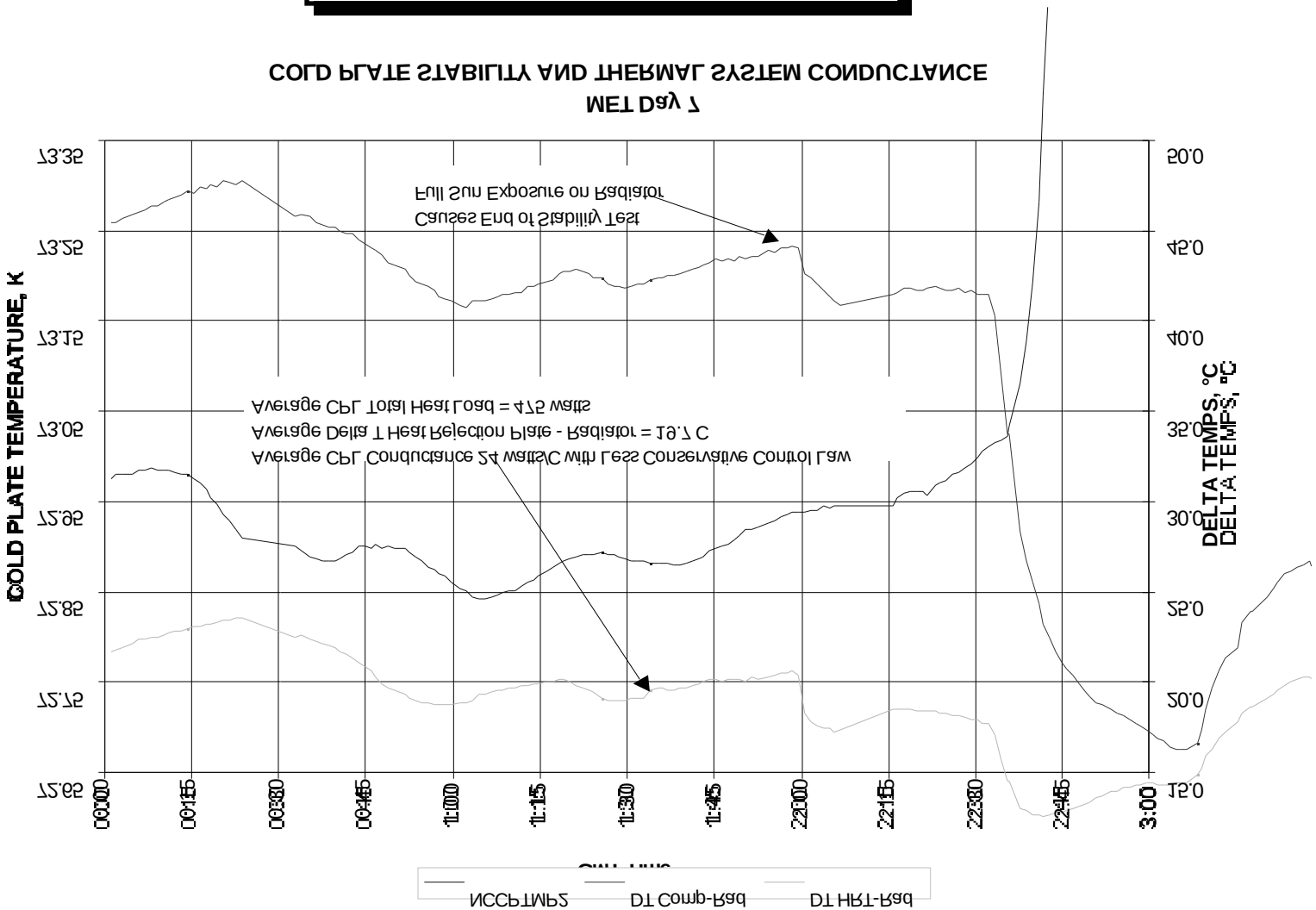
CPL/RADIATOR SYSTEM



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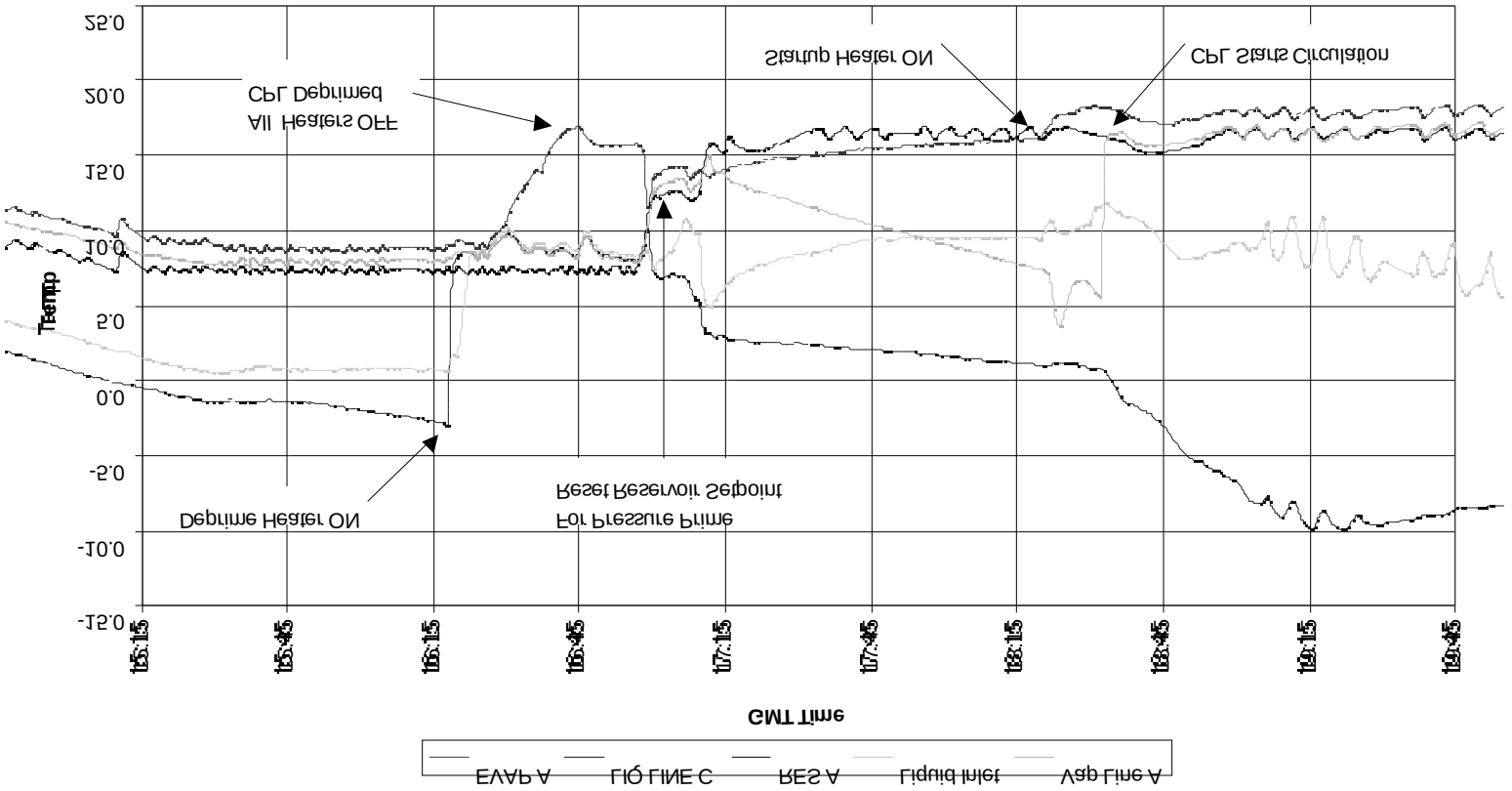
CPL/RADIATOR SYSTEM



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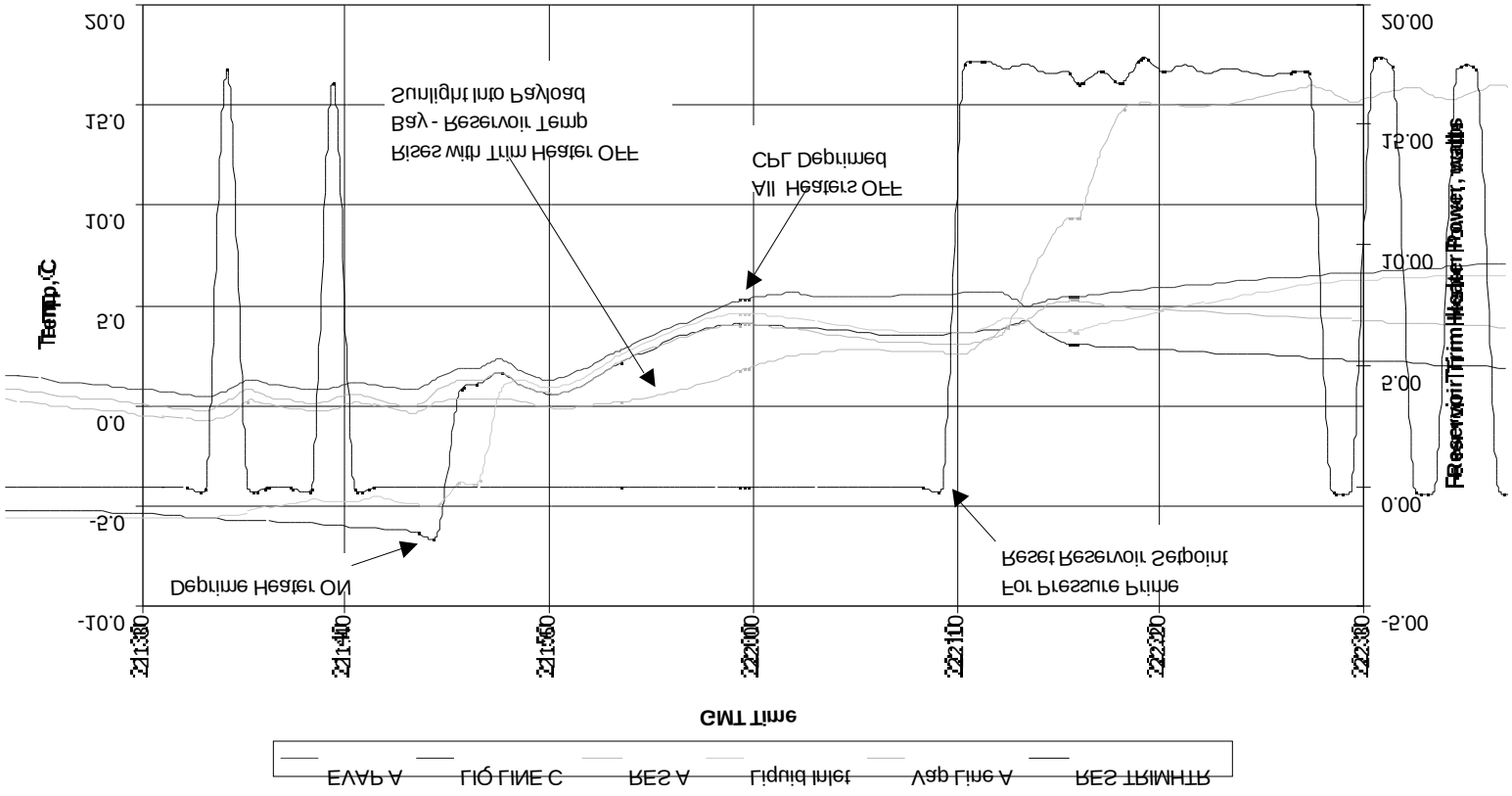
CPL/RADIATOR SYSTEM

CPL INTENTIONAL DEPRIME #2
MET Day 2
Sunlight in Payload Bay Causes Loss of Positive Control of Reservoir Temperature



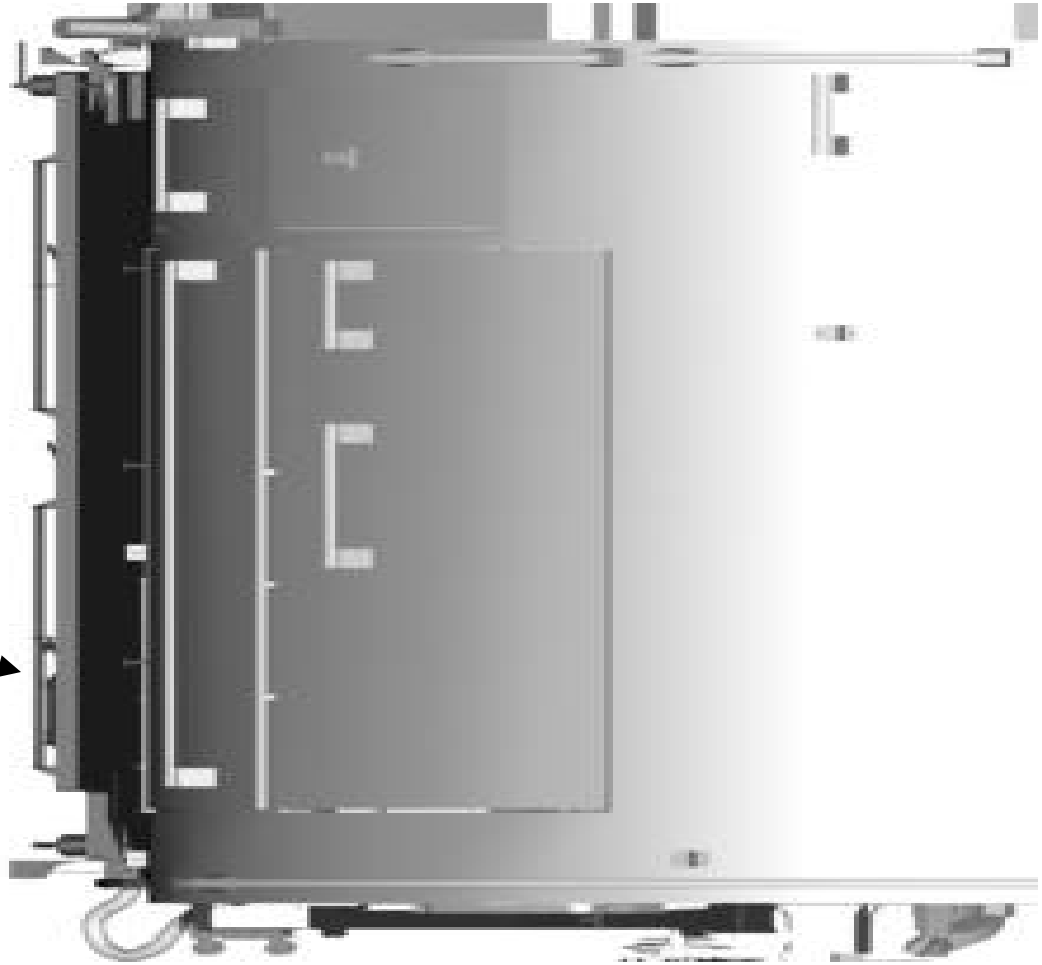
CPL/RADIATOR DESIGN CHANGES FOR SM3 BASED ON HOST FLIGHT DATA

- Additional blanketing/sunshield required to prevent direct solar flux on CPL reservoirs from causing loss of temperature control

- Near-deprime on MET Day 4 partially caused by fixed reservoir heater offset calculation in CPL Control Algorithm
  - Rapid orbital thermal environment changes disclosed problems not reproducible in T/V testing
  - Boost Heater (50 watts) automatically set at nominal 1°C below Trim Heater (15 watts)
  - Fixed number of counts were used to calculate offset in HOST software build
  - Non-linearity of thermistors caused Boost Heater to turn on at 2.1°C offset
  - Calculation error is already fixed in current SM3 software build

SM3 RADIATOR SOLAR FLUX

30° Roll Allows Direct Solar Flux On Reservoir: Need Additional Blanketing



Electronic Support Module (ESM)

Dr. Ed Cheung

Flight Software Performance

- 8051 code performed as in thermal vacuum testing.
- PID algorithm was used as soon as the NCC was ready for operational use (i.e., after successful startup sequence).
- Compressor maximum allowed speed was stepped up to control turbo-alternator speed during cooldown.
- Compressor Housing Temperature control law worked effectively to prevent over-temperature of the compressor housing.
- CPL control law operated as seen in T/V, including the known limitation to its accuracy.

Findings and Corrective Actions

- PID control law derivative of error calculation is sensitive to changes in the temperature setpoint. This caused one small compressor speed jump near the end of the mission. Software has been modified to eliminate this sensitivity.
- PID control law compressor speed smoothing prevented the compressor speed from reaching its user-defined upper limit. This was known in T/V. A software change has been made to correct this.
- CPL control law suffered from poor inverse calibration curve computations (known in T/V). Software change corrects this.

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Findings and Corrective Actions

- CPL control law needs to monitor more than just 2 ammonia temperatures around the CPL loop. Software change allows for expansion of observation and control points.

- PID control law was called once per minute during T/V and HOST. It should be called more frequently to allow faster changes in compressor speed (smoothing slows this change down already). No software modification necessary -- PID table load only.

SAMs

Darrell Story

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Post Mission Review

SAMS-FF

- **Mission Objective**
  - Evaluate the suitability of the NICMOS Cryo-Cooler System (NCS) for HST by measuring the vibration disturbances generated during the various modes of NCS operation
    - ⇨ Modal Frequencies
    - ⇨ Respective G-levels

- **Configuration**
  - One Control and Data Acquisition Unit (CDU) and two Triaxial Sensor Heads (TSH)
  - One TSH mounted on the cryocooler bridge plate and one TSH mounted on the NCC structure
  - Configuration designed to produce a relative vibration between the two sensor heads that will yield an absolute measure in the HST frame.

SAMS-FF

- **Results**
  - No on-orbit anomalies detected
  - Memory size permits 10,440 seconds of recording time with 10,115 seconds used (97% memory utilization)
  - 43 data files generated
    - ⇨ 41 data files recorded during HOST mission (255 secs each)
    - ⇨ 2 data files recorded during the IVT/ETE test at KSC (30 secs each)
  - Maintained log of SAMS-FF power cycle events, recording durations, number of data files in memory, and NCS/Orbiter activities.
  - SAMS-FF data successfully downloaded upon hardware arrival at GSFC on Dec 1, 1998

SAMS-FF

- **Data Gathered During Mission**

Event	Free Drift	Cryo-TSU Off	Compressor Speed	System Temp	Crew Sleep	Critical Measurement Priority
Baseline calibration measurement at mission start	X	X				1
Shuttle signature acquisition at mission start		X				
Compressor warm start		X	5000 rps	295K		
Circulator warm start		X	1500 rps	295K		
Turbine load switch activity		X	6000 rps	295K		
Compressor max speed during surging		X	6600 rps	270K		
Intermediate *surge* sample during max cooldown profile		X	7150 rps	122K		
Intermediate *non-surge* sample during max cooldown profile		X	7175 rps	90K		
Sample during period characteristic of nominal science ops	X	X	7150 rps	PID set-point = 78.5K		5
Idle mode characterization		X	6450 rps	PID set-point = 90K	X	
Compressor max speed at cold			7318 rps	72.6K		3
Sample during period characteristic of nominal science ops		X	7222 rps	PID set-point = 72.8K	X	4
Circulator cold start			1500 rps	72.8K		
Compressor cold start (may not be recorded)			5000 rps	72.8K		
Baseline calibration measurement at mission end	X	X				2

SAMS-FF

- **Changes For SM-3 Qualification Program**
  - Not applicable

- **Open Issues and Remaining Work**

1 - The LeRC PI Microgravity Services data-analysis team will
   - ⇨ Produce PSDs in each of six axes
   - ⇨ Identify all non-NCS activities during data record periods
   - ⇨ Remove or window around non-NCS artifacts for the PSD analysis

2 - The GSFC data-analysis team will
   - ⇨ Further reduce the results from (1) above, and
   - ⇨ Quantify as jitter in the HST frame

3 - Data analysis schedule
   - ⇨ Prioritized critical system data reduced by end of Jan. 1999
   - ⇨ All other data reduced by March 1999

SSR

Joe Forsyth

SSR Experiment Overview

- **Mission Goals**
  - Determine if unit F2 (SM3) experiences 1773 bus errors and repeatable bulk memory errors as does unit F1 (SM2 HST SSR-1)
  - Document and quantify any additional anomalies resulting from latent faults
- **Configuration**
  - Power converter A
  - 1773 primary bus A, retry bus B
  - Both memory cards used as one data storage area (~12 Gbit total)
  - 1.024 Mbps port 1 record (1/0 fill data input) simultaneous with port 2 playback
  - Contained within transport module mounted to HOST carrier

SSR Mission Results

- **HOST**
  - 14.6 1773 I/O card bus errors per day average, 120 total
  - 0 1773 I/O card bus retry failures
  - 3.5 correctable EDAC errors per day average, 28 total
  - No additional bus errors or repeatable EDAC errors
  - No additional anomalies

- **Comparison to HST for Same Time Period**
  - 42.8 1773 I/O card bus errors per day average
  - 1.2 1773 I/O card bus retry failures per day average
  - 1.2 correctable EDAC errors per day average
  - 3 areas of repeatable correctable EDAC errors in bulk memory

- **Data has yet to be correlated with PHA's**

HOST/ HST Differences

- HOST's orbit lower than HST's by 20 miles
- Orientation and mechanical configuration
- "Stale" data volume on HOST approximately 6 Gbit, HST averages 2 Gbit
- HOST SSR was continuously recording and playing back data, HST SSR operates in accordance with science and TDRSS schedules

Changes & Conclusions

- **Changes to SSR for SM3**
  - No changes recommended for SSR hardware.
  - No changes recommended for SSR test programs.
- **Conclusion**
  - HOST has demonstrated that SSR F2 will successfully meet HST mission requirements without altering its hardware or pre-flight test plan.

PHA

G. Stassinopoulis

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PHA

- **Objective**
  - Measure the energy deposited by:
    - ⇨ Galactic and Solar Cosmic Rays
    - ⇨ Their daughter products from interaction with spacecraft materials
    - ⇨ Spallation, fractionation, or recoil products from energetic trapped protons

- **Results**
  - The PHA instrument preformed nominally throughout the HOST Mission
    - ⇨ Recorded 15 abnormal bursts during the mission
  - Measurements of trapped protons induced events within the SAA were at expected levels.
  - Galatic Cosmic Rays events outside the SAA were also within expected leaves for the low inclination of the STS-95 mission

PHA

- **Remaining Activity**
  - Systematic analysis of mission data to correlate Shuttle attitude, altitude, trapped particles, and magnetic parameters B, L and Rigidity.
  - Comparison and correlation with SSR data.
  - Resolving cause and identifying source of abnormal bursts.

HOST Controller

Dr. Ed Cheung

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Controller

- **Mission Objective**
  - Provide C&DH for experiments on HOST cradle
  - Provide 1 level of safing for the NCS
  - Provide experiment data stream for FOFE
  - Test flight for ESN MCM and associated computer boards

- **Configuration**
  - Processed uplink commands from the Orbiter PSP
  - Supplied downlink telemetry to Orbiter PDI
  - Managed experiment activities
    - ⇨ NCS, HST486, SSR, PHA, SAMS, FOFE

Controller

- **Results**
  - Overall operation of the Controller was very successful
    - ⇨ No command drops attributable to Controller hardware or software
    - ⇨ No impact on science due to Controller problem or anomaly
    - ⇨ No radiation hits detected on analog or digital hardware
  - Controller Software
    - ⇨ Performed reliably on orbit
    - ⇨ Transferable for future commercial and NASA missions

- **Changes For SM-3 Qualification Program**
  - Not applicable

Controller

- **Open Issues and Remaining Work**

  – Occasional (twice per day) '0x00FF' telemetry in the 'Cmd Echo' field. This should always be zero. Most likely an uplink problem.

  – (For reflight) Replacement of ESN Computer Board with flight spare from Engineering Model will alleviate temperature constraint.

  – (For reflight) Investigation of Side-A on PSK Demodulator Board to address commands dropped during I&T. This side not used during mission.

FOFE

Russ Burgess

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FOFE

- **Mission Objective**
  - Evaluate fiber optic performance in the Shuttle environment with the long term goal of standardizing payload interfaces thereby reducing OPF processing time.
  - The KSC / JSC Shuttle Payload Upgrades Team partnered with GSFC to conduct the Fiber Optic Flight Experiment (FOFE) on the HOST Mission.

- **Configuration**
  - MIL-STD 1773, 1300nm fiber optic interface between the Remote Terminal (RT) installed in the HOST Controller and the Bus Controller (BC), a dedicated PGSC in the AFD.

FOFE

- **Data Gathered During Mission**
  - FOFE setup and activation was completed by the Crew at 303/18:30 GMT and deactivated at 310/12:32 GMT when the PGSC hard disk was filled to capacity.
  - 7,792 files (165 MB) of data were collected for comparison to the data recorded by the HOST POCC.
  - Three dumps were downlinked during the mission via the OCA on the KU-band.
    - ⇨ Data consists of two types of file for each 100-second record segment:
      - Bit Error Rate (BER) results
      - HOST data

FOFE

- **Results**
  - Downlinked data (representing 0.2% of data collected) verified during the mission
    - ⇨ Fifteen BER files indicated that no bit errors and no failures requiring A/B channel switching.
    - ⇨ Fifteen HOST data files verified via CRC at the POCC. The vendor compared these files to corresponding data collected by TMS. No miscompares between HOST data and FOFE downlinked data.
  - Data collection on-orbit interrupted 13 times
    - ⇨ Crew reported 6 software crashes.
    - ⇨ 6 unspecified cancellations of data requests by the BC.
    - ⇨ Disk full (expected).
  - The complete hardware compliment shipped directly to the vendor for evaluation and complete data deintegration

Systems Engineering

Keven McAveety

HOST

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Systems Engineering Mission Results

- **HOST Mission Success**
  - Platform Operated as Expected
  - All Mission Objectives Met
- **HST Experiments Proved Worthy of Flight for SM3**
- **Orbit Altitude Met Mission Success Criteria**
  - Mission Success Criterion: 295 nm
  - Orbit Achieved: 305 x 295 nm
  - For HST486 and SSR Radiation Exposure

Systems Engineering
Mission Results (continued)

- **No Significant HARs Opened**
  - HAR 1159, HST486 Thermistor B Bias
  - HAR 1160, SSR Correctable EDAC Errors
  - HAR 1161, FOFE On-Orbit Anomalies
  - HAR 1162, NCS Trim / Boost Offset in Control Law

- **Space Shuttle Environments Warmer Than Expected**
  - More / longer sun looking attitudes
  - Caused warmer platform temperatures (e.g., NCS Radiator and HOST Controller)
  - Caused NCS cooldown times longer than expected and difficulty in reaching target temperature at coldplate
  - Not a problem for HST / SM3: NCS and ASCS radiators will see much colder environments

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Systems Engineering

Mission Results (continued)

- **Weight, Power, and Energy Usage within Allocations and Performance Budgets (predictions)**
  - Allocations and budgets as presented at Pre-Ship Readiness Review

- **HOST Power and Energy Budget**
  - Peak power and energy usage were within allocations
  - Actual energy consumption was 20% less than allocation
  - Lower energy consumption due to warmer environments (lower heater duty cycles), margin in budget, and uncertainty in telemetry readings

- **NCC Power Consumption**
  - NCC Power Consumption compared well with HOST T/V measurements

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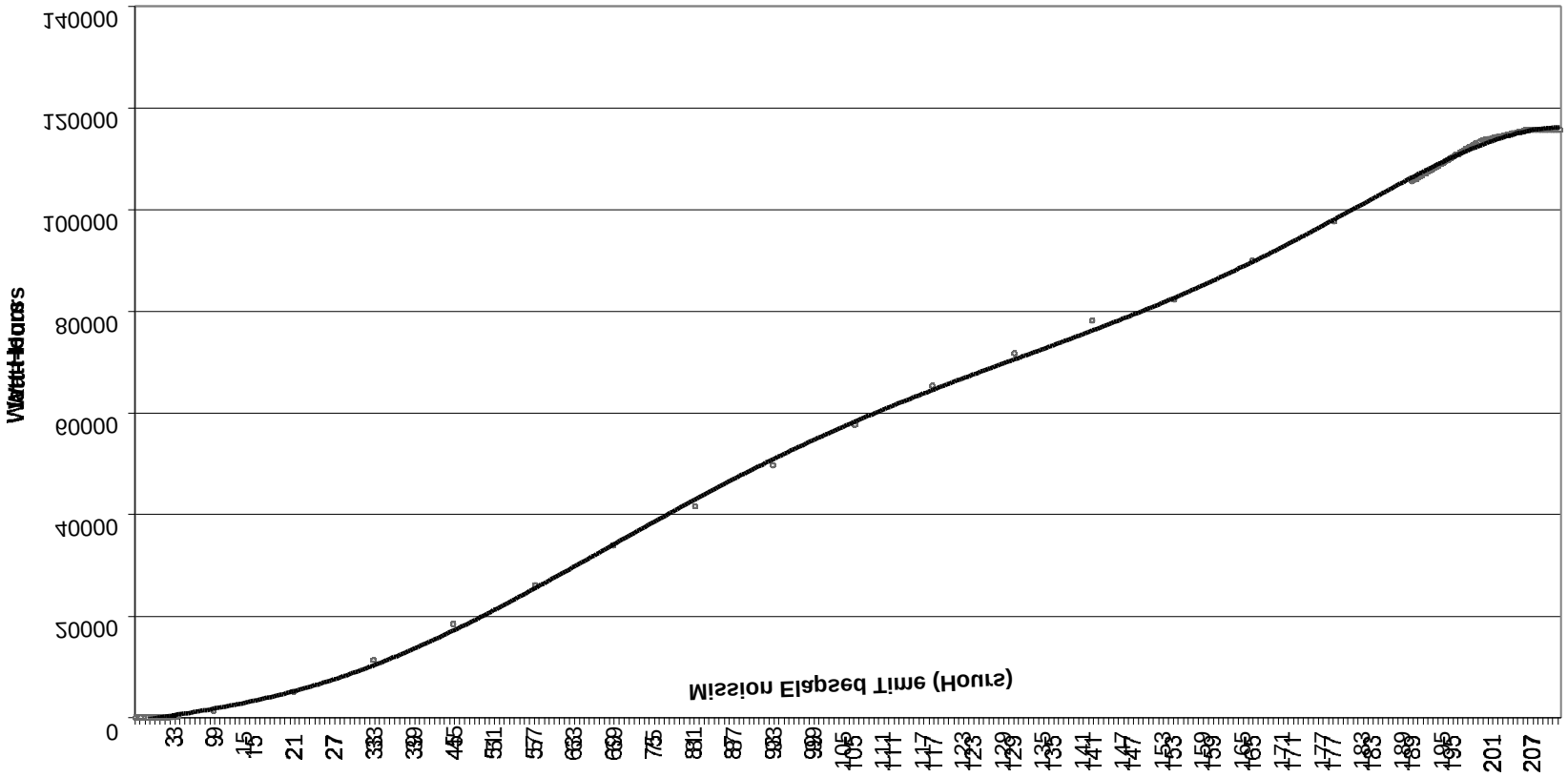
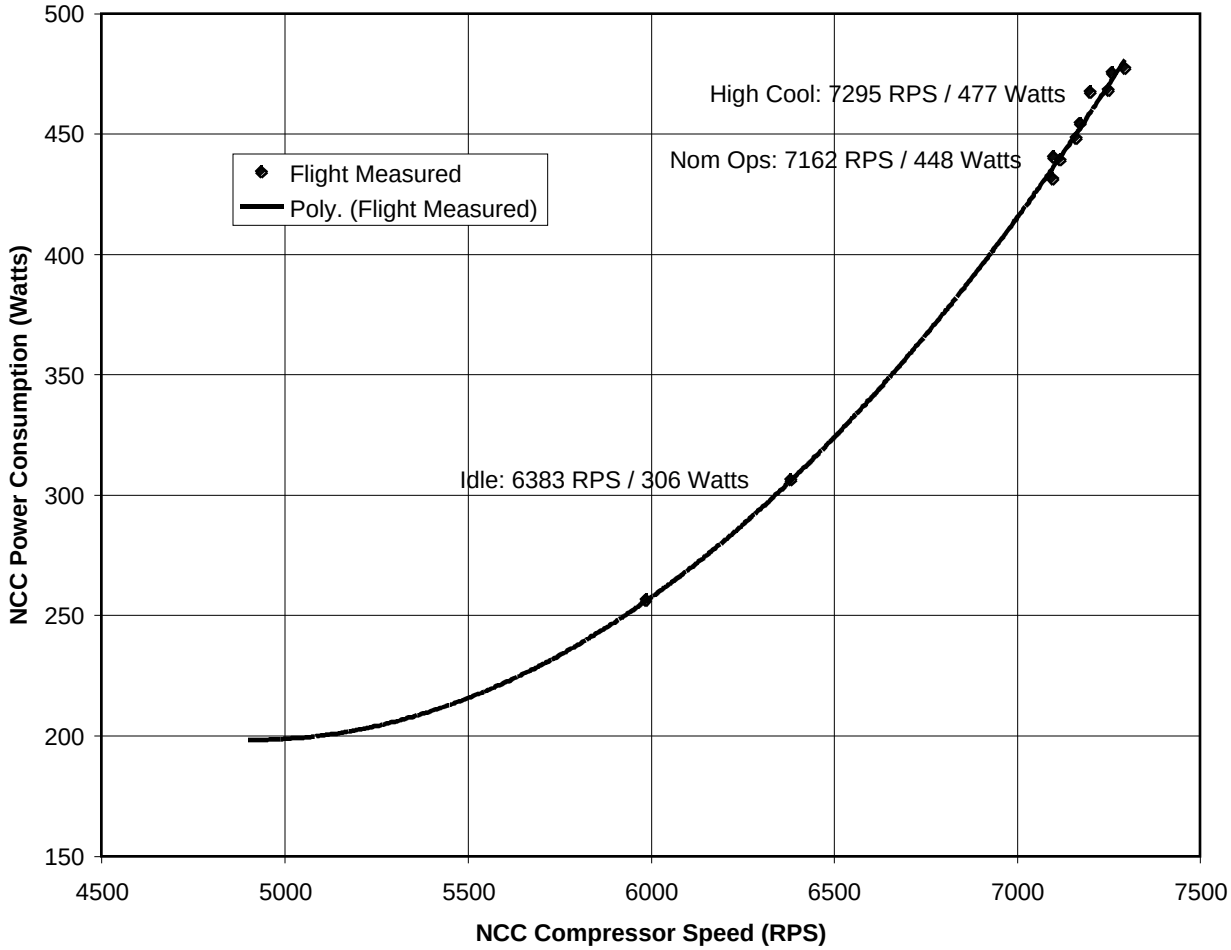
Mission Results

(continued) Platform

Energy Consumption



Mission Results (continued) NCC Power Consumption



Systems Engineering
HST SM3 Hardware Summary

- **HST486 - Advanced Computer**
  - All Three Processor Strings Demonstrated
  - Interfaces and Processor Operation Similar to HST
  - No Radiation Induced Errors (SEU or Latch-Up) Experienced During HOST Mission
    - ⇨ Demonstrates No 'Weak Link' in Radiation Testing and Analysis
    - ⇨ EEE Parts Test Plan Valid
  - 486 Design Acceptable for HST Installation Pending Successful Test Program

Systems Engineering
HST SM3 hardware Summary

- **Solid State Recorder (SSR)**
  - Radiation Behavior of HOST Tested SSR Similar to HST Installed Unit
  - Lower Fiber Bus (1773) Errors Due to Lower Flux
  - Higher Mass Memory EDAC Errors Due to Configuration and Memory Management of Recorders
  - Closure of SSR ARB Can Be Formulated
  - SSR Acceptable for HST Installation Pending Successful Test Program

Systems Engineering
HST SM3 Hardware Summary

- **NICMOS Cooling System (NCS) / Aft Shroud Cooling System (ASCS)**
  - CPL Operated as Expected
  - NCC Operated as Expected
  - Achieved Cold Temperature of 72.6 K
    - ⇨ HST Requirement: 72 K, Goal: 70 K
  - Orbiter Sun Pointing / Hot Attitudes Prevented Driving Colder, BUT Slope of Cold Dome During Cold Attitudes Provides Confidence That HST Requirement Could Have Been Met
  - HOST Mission Demonstrated In-Flight Operation of NCC / CPL Systems Mimics Ground Operation
  - Valuable Information Learned Which May Not Have Been Possible Without HOST Mission
    - ⇨ Rapid Environment Changes
    - ⇨ Solar Impingement on Reservoir